Строительные материалы и изделия
Construction Materials and Products

journal homepage: https://bstu-journals.ru

ISSN
2618-7183

DOI: 10.58224/2618-7183-2026-9-2-2

Distinguishing characteristics of the molding properties of ceramic masses based on siliceous opoka-like rocks for the production of large-format porous stones using the rigid extrusion method

Zemlyanskaya A.G. * [1]

[1] Don State Technical University, Russia

Abstract: The article analyzes the main technological approaches to controlling the molding properties of ceramic compounds based on opoka-like rocks – highly porous siliceous rocks for the production of large-format wall blocks by rigid extrusion with horizontal voids. Opoka-like rocks, which are siliceous sedimentary formations, have high dispersion, porosity and a significant content of amorphous silica. Their use in the production of building ceramics makes it possible to reduce the density of products, improve thermal insulation properties and reduce energy consumption for firing. The low plasticity of opoka-like raw materials complicates their molding using traditional methods. Therefore, rigid extrusion represents an effective technological solution for producing parts with complex geometries and specified physical and mechanical properties, while reducing the energy consumption of the process, making it preferable for use in modern, environmentally friendly industries.

Keywords: high-void large-format ceramic stones, porous ceramics, rigid extrusion, molding moisture, pressing pressure, siliceous rocks, opoka

Please cite this article as: Zemlyanskaya A.G. Distinguishing characteristics of the molding properties of ceramic masses based on siliceous opoka-like rocks for the production of large-format porous stones using the rigid extrusion method. Construction Materials and Products. 2026. 9 (2). 2. DOI: 10.58224/2618-7183-2026-9-2-2

1. INTRODUCTION

The growing demands for energy efficiency and environmental safety of buildings stimulate the development of the production of wall materials with enhanced thermal protection properties. Among them, large-format ceramic porous blocks and blocks made of autoclaved aerated concrete have become the most widespread. Both materials have a low density (less than 800 kg/m3) and high thermal insulation properties, but their operational and technological characteristics differ

---

*Corresponding author E-mail: ya@azemljanskaja.ru

Received November 17, 2025; Received in revised form January 13, 2026; Accepted March 16, 2026

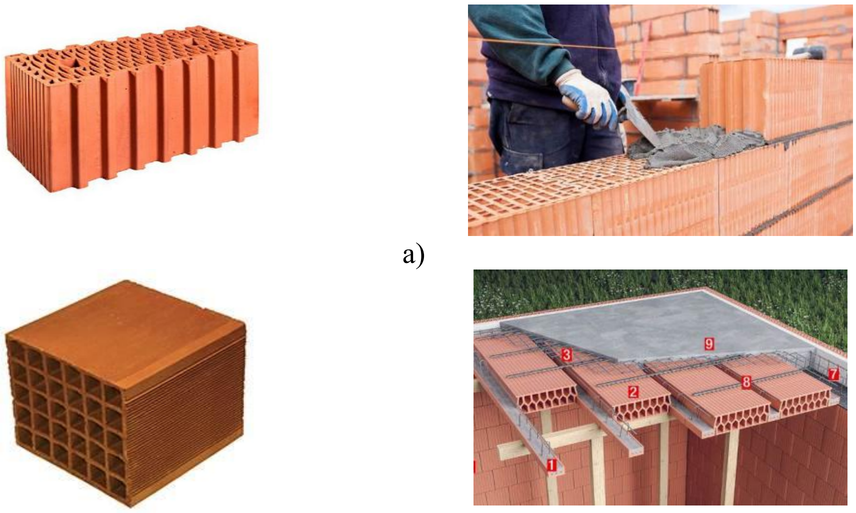
significantly. Aerated concrete blocks are widely used at construction sites as enclosing materials in monolithic frame construction. These blocks have attractive reduced cost and are available on the construction materials market. If we compare aerated concrete with large-format ceramic blocks, they have approximately the same thermal conductivity. For grades D 500–D600, the thermal conductivity coefficient is 0.12–0.14 W/(m•°C). Ceramic blocks, such as Porotherm 51, have a thermal insulation value of 0.143 W/(m•°C), which meets modern thermal insulation standards. However, wall ceramics maintain stable thermal performance in humid conditions, whereas aerated concrete is prone to increased humidity and decreased thermal insulation. Ceramic blocks have the required vapor permeability, which promotes natural moisture exchange and the creation of a favorable indoor microclimate. Aerated concrete is more hygroscopic, requiring additional vapor barriers or ventilated facades. Ceramics also have low water absorption, increasing their durability in conditions of variable humidity. Frost resistance of ceramic blocks reaches F50–F75 cycles, exceeding the performance of most aerated concrete grades (F15–F35).

This makes ceramics preferable for regions with severe climates. Ceramic blocks can be manufactured from various natural mineral raw materials (clays, argillites, coal waste), which reduces costs and is a pressing issue given current environmental concerns. The use of tongue-and-groove system reduces mortar consumption and speeds up construction. Although aerated concrete is energy efficient, it requires the use of special adhesives and additional facade finishing, which increases overall costs. Aerated ceramic blocks are characterized by higher compression strength—from 7.5 to 12.5 MPa (grades M75–M100), allowing them to be used in load-bearing walls of multi-story buildings. Autoclaved aerated concrete has a strength of 2.0–4.5 MPa, which limits its use in heavily loaded structures. The predetermined shape of ceramic blocks allows for the creation of complex architectural forms (bay windows, arches, curved walls) without compromising strength or thermal insulation. They are compatible with traditional brickwork, slabs, and lintels, simplifying integration into projects of varying complexity. Therefore, ceramic aerated stone outperforms autoclaved aerated concrete blocks in strength, frost resistance, and thermal stability in humid conditions. The high vapor permeability and low water absorption of ceramics contribute to a healthy microclimate and the durability of structures. The use of local raw materials and industrial waste makes the production of ceramic blocks economically and environmentally friendly. Despite a higher initial cost, ceramic blocks offer reduced operating costs due to their durability and energy efficiency. Therefore, ceramic aerated stone is a more promising material for modern construction, especially where reliability, energy efficiency, and environmental friendliness are paramount.

The relevance of developing and implementing highly efficient wall materials that combine low thermal conductivity with sufficient structural strength is due to stricter standards for energy conservation in construction. Traditionally, a decrease in the thermal conductivity of wall blocks has been achieved mainly by increasing the geometric voidness. Analyzing the experience of foreign builders, we can see the high popularity of ceramic high-void stones (with a voidness of up to 70%). These products are used to fill openings of frame structures and in low-rise construction. In this case, the voids in the products can be positioned perpendicular (vertical) or parallel (horizontal) to the bed, in accordance with GOST 530-2012. When considering the thermal properties of wall products of such different designs, it can be seen that, at first sight, the ceramic stones with vertical voidness appear to "preserve" air convection within the narrow columns due to the large "channel" height-to-width ratio and reduced air circulation. However, the vertical lintels themselves can act as thermal bridges, facilitating heat loss from bottom to top. In stones with horizontally arranged voids, the heat flow is perpendicular to the lintels, and once warm air passes through them, it reenters the airspace, preventing heat loss.

Also, during installation work using ceramic horizontally hollow blocks with side joints, the masonry mortar is applied only to the vertical surface, which prevents it from falling into voids, as can often be seen when masonry is made of vertically hollow stones (Fig. 1). Such a system has better resistance to bending loads and increased wind protection. Another advantage of ceramic large-format stones with horizontal voidness is improved acoustic properties due to the possibility of providing greater voidness (up to 70%), with such an arrangement of voids, enlarged internal cavities have increased sound insulation characteristics, and internal communications can also be placed in the formed horizontal cavities without the need for additional chases.

Thus, ceramic stones with horizontal voids can become quite promising for manufacturers of wall products, providing accelerated rates of construction of energy-efficient buildings with high reliability of the material under various loads, increased thermal protection and sound insulation characteristics.



a)

b)

Fig. 1. a) – An example of ceramic stone with vertical voids and a variant of masonry with vertically hollow stones; b) – An example of ceramic stone with horizontal voids and a variant of masonry with horizontally hollow stones.

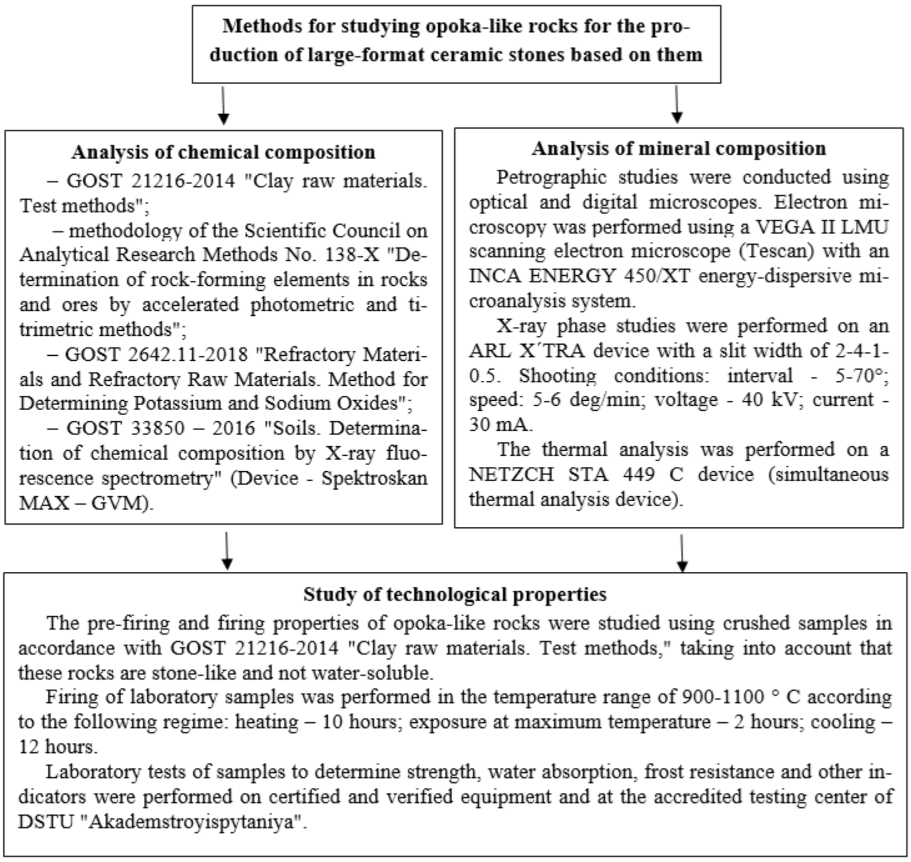
Currently, it is quite important to control the porization processes, that is, the creation of pores in the required quantity and with the required size [1-2]. It's essential to combine correctly macrovoids with the developed microporosity of the material itself. This not only radically improves thermal performance but also solves problems inherent in high-voids products: the wedge effect of mortar, reduced masonry strength, and installation difficulties. Based on an analysis of recent research and industrial developments, several fundamental technological approaches to creating porous ceramic bodies can be identified, each with a unique mechanism and application niche. The first approach is the use of burnout additives [3-5]. This is the most technologically advanced approach, based on the introduction of dispersed organic or mineral components into the raw material mixture, which are oxidized during the firing process to form gaseous products. Traditionally, these additives include: organic waste such as sawdust, straw flour, and lignin; industrial raw materials and processing waste such as coal dust, flotation sludge, and processing waste; and synthetic materials such as expanded polystyrene (historically used in the Poroton technology) [6-7]. When heated in the range of 300-900 ° C, such additives burn out, leaving behind a system of closed or communicating pores. The size and nature of the porosity depend on the dispersion of the additive, its quantity and firing mode. At the same time, coal sludge, for example, performs not only a pore-forming, but also a fuel-containing function, allowing saving up to 80% of the gas for firing, and also acts as a plasticizer, improving the molding properties of low-plastic masses. This technology critically depends on the gas permeability of the raw material mass. In dense clay charge materials, incomplete burn out of the additive is possible, leading to defects and a decrease in strength. In addition, the high content of burning-out components (over 20-25%) often leads to an unacceptable loss of structural strength [8]. The second method is the swelling method (foam and gas formation). This group of methods is based on creating a cellular structure directly in a liquid or plastic molding compound before or during the initial firing stage. Such methods include: foaming: mechanical or chemical foaming of a slip, followed by foam stabilization and solidification, which allows to obtain materials with extremely low density (250-700 kg/m3); low-temperature gas formation associated with the introduction of gas-forming reagents (for example, aluminum powder) into the mass, which react with the release of gas at normal temperatures; high-temperature swelling when using raw materials (special swelling clays) or additives that release gas at high firing temperatures (similar to the production of expanded clay) [9-11]. The main breakthrough of such methods was the solution of the problem of stabilizing the foam structure without the use of additives, such as gypsum. Modern developments (P.P. Budnikov All-Russian Scientific Research Institute of Building Materials and Structures) are based on controlling the coagulation of the clay component, which eliminates the need for gypsum, increase the strength of the raw material and reduce shrinkage. An analysis of recent works by Russian scientists (Kotlyar V.D., Zemlyanskaya A.G., etc.) indicates a new trend – a shift away from scarce, highly plastic clays in favor of a widely available, non-traditional raw material: opokas [12-17]. Opokas, natural microporous rocks, are offered as the primary raw material. Their advantages include natural microporosity, which forms the basis for a highly porous ceramic body with a density of 1.3–1.6 g/cm³. The uniform distribution of pores within the products is determined primarily by the chemical and mineralogical composition of the mass and, secondarily, by the selected technological parameters of the molding, drying, and firing processes. When using siliceous opoka-like rocks, the ceramic products themselves possess the natural porous structure of the fired material.

There are several methods for producing wall products using clay raw materials: semi-dry, plastic, and rigid extrusion. For opoka-like materials, the traditional plastic molding method is less suitable. For siliceous rocks, the semi-dry molding method is most often used, with a molding clay moisture content of 8–12% and a pressing pressure of 25–40 MPa. This technology involves tight compression of the prepared press powder until the required contact between the particles is achieved for subsequent clinkering. This method is typically used to produce small-size ceramic products, such as bricks and tiles. When producing large-format, highly hollow stones, this method faces a number of limitations: difficulty removing air from a large press mold, which can lead to defects, decompaction, and reduced strength of the fired stones; inability to form the required void pattern (which can reach up to 50-70% in products); and the impossibility of creating a tongue-and-groove system in ceramic blocks, if present. Furthermore, the introduction of burnable components into the ceramic charge materal is difficult due to the uneven distribution of light additives in the molding powder, resulting in ceramic body with varying porosity and density. Furthermore, the increased pressures associated with the semi-dry pressing method predetermine high energy consumption during production and rapid equipment wear. Therefore, the hard extrusion method is the most suitable for opoka-like siliceous rocks. The stone-like structure of the opokas is ideal for molding products using rigid extrusion, allowing for the modernization of older plants without increased investment. The moisture content of the ceramic charge material based on opokas with developed natural microporosity in this production method can reach 30–40%, with pressing pressures of 2.5–4.0 MPa in a vacuum environment. This allows for the following: high compaction of the mass; removal of air inclusions; improved structural homogeneity; and the ability to mold products with thin walls and complex voids. For opoka-like rocks, the preparation of the charge material is critically important, including fine grinding, mixing with plasticizing additives (e.g., bentonite clays) and pore-forming components (burnout additives, straw flour). Thanks to the rigid extrusion method, opoka-like rocks can be used to produce products with the following: compression strength of 7.5–12.5 MPa; frost resistance of F35–F75 cycles; thermal conductivity coefficient of 0.14–0.16 W/(m °C); high geometric accuracy (deviations of ±1 mm). Compared to semi-dry pressing and plastic molding, rigid extrusion allows for: increased productivity due to the continuity of the process; reduced energy costs for drying; improved surface quality and dimensional accuracy; expanded product range (blocks, tiles, facade elements). The rigid extrusion method is particularly effective for the production of large-format porous stones that combine high load-bearing capacity and thermal insulation properties. Based on the work of V.D. Kotlyar, the mechanical, rheological and structural aspects that determine the resistance of freshly moulded products to deformation and damage during transportation and placement in the furnace were analyzed. He proposed scientifically sound ways to increase the technological strength of raw bricks to reduce the number of defective products and improve firing efficiency. V.D. Kotlyar emphasized that the use of low-plasticity mineral raw material systems, such as opoka-like rocks, requires special attention to the formation of the strength of the raw material already at the molding stage. In this regard, experiments were conducted to study ways to control the technological properties of ceramic masses based on opokas by rigid extrusion, which makes it possible to produce large-format stones with horizontal voids (with a voidness of up to 70%).

2. METHODS AND MATERIALS

In order to study the required parameters of opoka-like raw materials for obtaining the most durable and dense freshly molded raw products using the rigid extrusion method, we studied ceramic masses based on “normal” varieties of opoka, which include Avilo-Federovsky deposit and “clay” opoka from Shevchenkovskoye deposit [14].

In order to study the technological properties of opoka-like raw materials, experimental work was performed in accordance with the methods presented in Fig. 2.



Methods for studying opoka-like rocks for the production of large-format ceramic stones based on them

Analysis of chemical composition

– GOST 21216-2014 "Clay raw materials. Test methods";

– methodology of the Scientific Council on Analytical Research Methods No. 138-X "Determination of rock-forming elements in rocks and ores by accelerated photometric and titrimetric methods";

– GOST 2642.11-2018 "Refractory Materials and Refractory Raw Materials. Method for Determining Potassium and Sodium Oxides";

– GOST 33850 – 2016 "Soils. Determination of chemical composition by X-ray fluorescence spectrometry" (Device - Spektroskan MAX – GVM).

Analysis of mineral composition

Petrographic studies were conducted using optical and digital microscopes. Electron microscopy was performed using a VEGA II LMU scanning electron microscope (Tescan) with an INCA ENERGY 450/XT energy-dispersive microanalysis system.

X-ray phase studies were performed on an ARL X´TRA device with a slit width of 2-4-1-0.5. Shooting conditions: interval - 5-70°; speed: 5-6 deg/min; voltage - 40 kV; current - 30 mA.

The thermal analysis was performed on a NETZCH STA 449 C device (simultaneous thermal analysis device).

Study of technological properties

The pre-firing and firing properties of opoka-like rocks were studied using crushed samples in accordance with GOST 21216-2014 "Clay raw materials. Test methods," taking into account that these rocks are stone-like and not water-soluble.

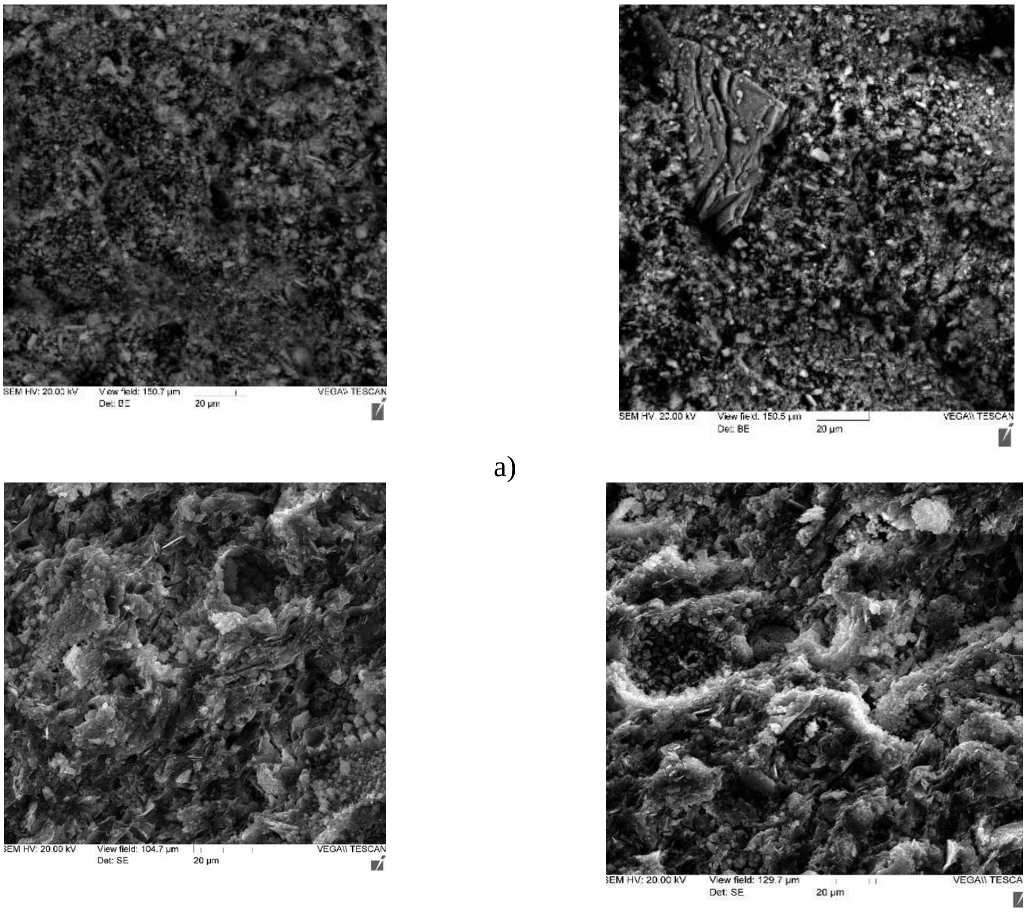
Firing of laboratory samples was performed in the temperature range of 900-1100 ° C according to the following regime: heating – 10 hours; exposure at maximum temperature – 2 hours; cooling – 12 hours.

Laboratory tests of samples to determine strength, water absorption, frost resistance and other indicators were performed on certified and verified equipment and at the accredited testing center of DSTU "Akademstroyispytaniya".

Fig. 2. Methods for studying pre-firing properties of opoka-like rocks in order to determine their suitability for the production of large-format ceramic stones.

The author of the article collected the opoka-like rock raw materials required for the study directly from Avilo-Fedorovsky and Shevchenkovsky deposits.

Chemical studies of rocks were performed in accordance with the methods specified in the regulatory documentation GOST 21216-2014 "Clay raw materials. Test methods", NSAM No. 138-X, GOST 2642.11-2018 "Refractory materials and refractory raw materials. Method for determining potassium and sodium oxides" and GOST 33850 – 2016 "Soils. Determination of chemical composition by X-ray fluorescence spectrometry" (Device – Spectroscan MAX – GVM). To perform petrographic analysis, thin sections were prepared and studied using conventional, digital and polarizing microscopes of various modifications. An ARL X'TRA device with a slit width of 2-4-1-0.5 was used for X-ray fluorescence analysis. Shooting conditions on the ARL X'TRA diffractometer: interval – 5-70°; speed: 5-6 deg/min; voltage – 40 kV; current – 30 mA. The thermal analysis was performed using a NETZCH STA 449 C device. The results obtained were interpreted using appropriate methods.



a)

b)

Fig. 3. Electron microscopic photographs of Avilo-Fedorovskoye deposit – (a); Shevchenkovskoe deposit – (b).

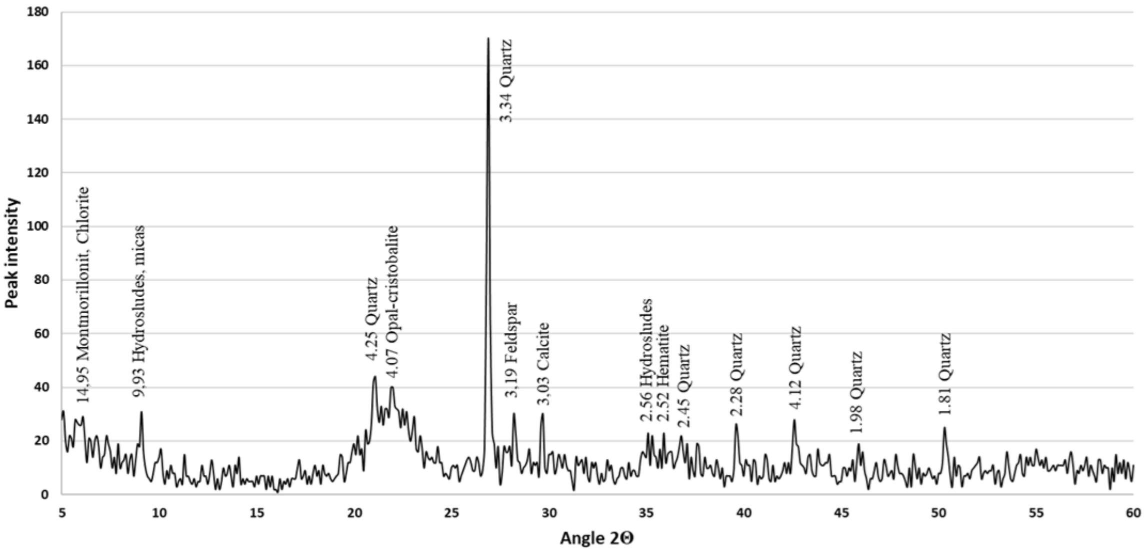


Fig. 4. X-ray image of Avilo-Fedorovskoye opoka deposit.

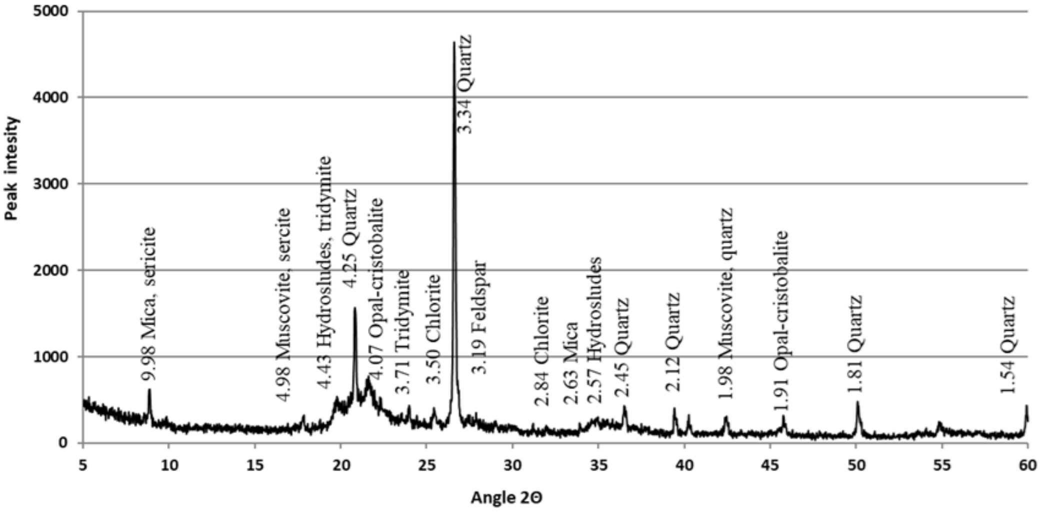


Fig. 5. X-ray image of Shevchenkovskoe opoka deposit.

To determine the oxide content of the studied opokas, a chemical analysis was performed, the results of which are presented in Table 1. A review of the chemical analysis results for the opokas from Avilo-Fedorovskoye and Shevchenkovskoe deposits revealed a high quartz oxide content, amounting to over 70%. Silica in the rocks can be present as opal, quartz oxide within clay inclusions, and terrigenous quartz. As can be seen from the chemical composition, the opokas from the Shevchenkovskoe deposit have a higher alumina content. Varying amounts of both AI2O3 and K2O and Na2O oxides, which are classified as flux oxides, indirectly determine the different technological properties of the studied rocks, including their plasticity and binding capacity. Potassium oxides also indicate the presence of micas and hydromicas in the opokas.

Table 1. Chemical composition of Avilo-Fedorovskoye opoka deposit and Shevchenkovskoe opoka deposit.

Deposit of opoka	SiO_2	AI_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	P_2O_5	TiO_2	Imps
Avilo-Fedorovskoye	71.90	7.94	4.23	2.79	1.11	0.37	1.69	0.30	0.06	0.62	5.42
Shevchenkovskoe	71.6	11.89	4.33	1.89	1.17	0.34	1.85	0.67	0.05	0.54	12.24

3. RESULTS AND DISCUSSION

The rigid extrusion method makes it possible to mold products, such as large-format stones, from ceramic masses with moisture contents up to 40% and pressing pressures no greater than 10 MPa at high compression and compaction. The increased microporosity of opoka-like rocks produced by this method allows to reduce drying costs or do without this process altogether, as well as to use raw materials with low plasticity. Therefore, it is important to study the feasibility of rigid extrusion for opokas with different chemical and mineral compositions. Given the technological characteristics of opoka-like raw materials and the low strength of raw materials, the following parameters were selected for study: molding moisture content and required pressing pressure, to determine their influence on the strength of raw materials samples and their density. For this purpose, ceramic masses were formed from rocks of Avilo-Fedorovsky and Shevchenkovsky deposits based on preliminary experimental work, with the fractional composition indicated in Table 2. A finer grinding of siliceous raw materials, as already determined in the studies of Kotlyar V.D. and Zemlyanskaya A.G., makes it possible to increase the plastic properties of molding masses, which leads to a decrease in their air shrinkage and, accordingly, a reduction in the risk of defects appearing after the drying and firing processes [14]. An increased degree of grinding of opokas makes it possible to break the tight bond of clay minerals with opal, which contributes to the improvement of the technological properties of stone-like raw materials.

Table 2. Grain composition of crushed opoka of fraction 0-0.5 mm from Avilo-Fedorovskoye and Shevchenkovskoe deposit.

Content of individual fractions, mm, % by weight		
0.05-0,5	0.01-0.05	< 0.01
18-22	47-53	28-32

During the tests, patterns were obtained regarding the influence of pressing pressure at different raw material moisture contents on the strength of freshly molded samples from Avilo-Fedorovskoye and Shevchenkovskoye deposits, shown in Fig. 6 and 7. For the "normal" varieties of opokas, which include the rock from Avilo-Fedorovskoye deposit, which has increased porosity, the molding moisture content was in the range of 20-40%, while the opoka-like raw material from the Shevchenkovskoye deposit had a molding moisture content of 10-30%.

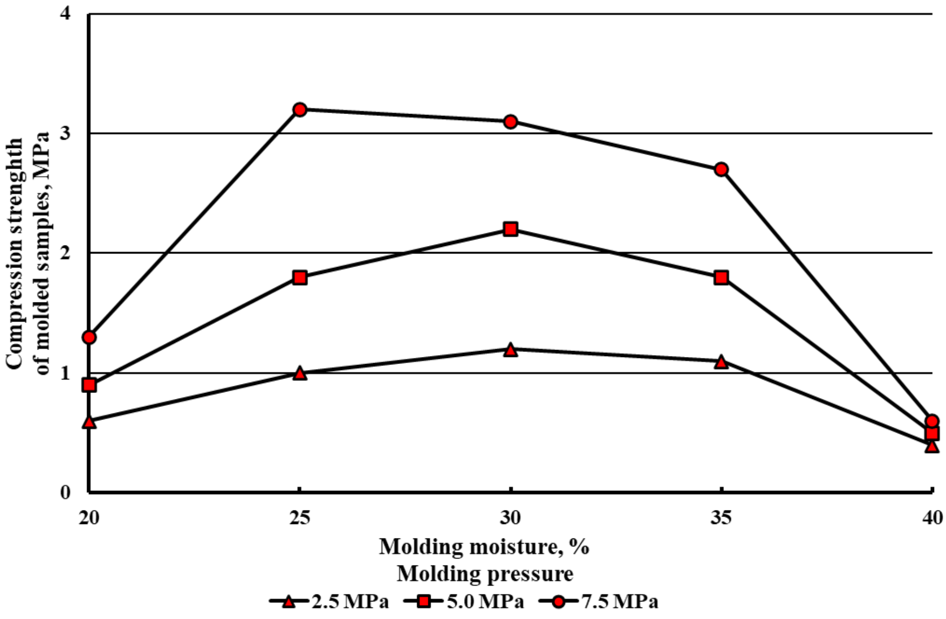


Fig. 6. The dependence of the compression strength of freshly molded samples on the pressing pressure at different molding moisture contents of ceramic mass based on the opoka of Avilo-Fedorovskoye deposit.

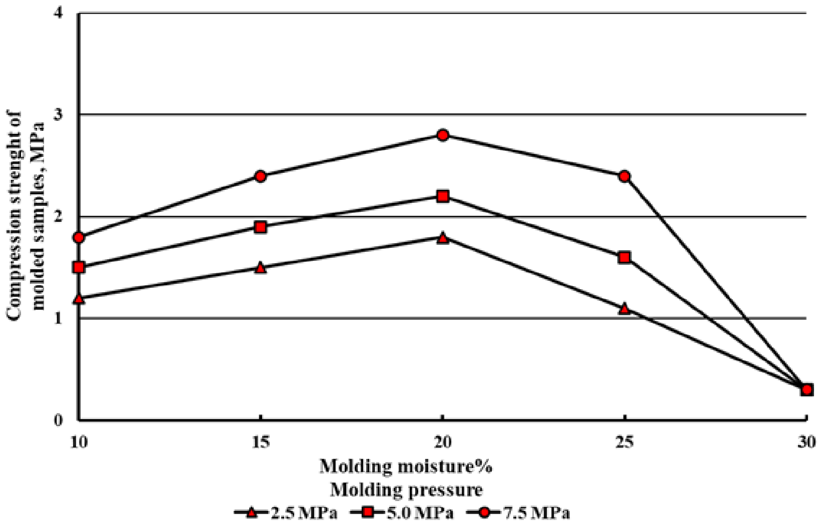


Fig. 7. The dependence of the compression strength of freshly molded samples on the pressing pressure at different molding moisture contents of the ceramic mass based on the opoka of Shevchenkovskoe deposit.

Analyzing the obtained curves, we can trace the following general trend for the two studied opokas: with increasing pressing pressure, the degree of compaction of the samples increases due to the removal of air and the formation of evenly distributed voids of a complex structure, compaction of ceramic charge material particles. At the same time, an increase in the strength of raw materials was observed at a moisture content of Avilo-Fedorovskaya opoka from 20 to 30%, for the opoka of Shevchenkovsky deposit from 10% to 20%. After a further increase in moisture content in the studied raw materials, the strength of the pressed samples decreased due to an overabundance of water in the pore space and decompaction of the products [14]. The strength of freshly molded products with a value of 1.0 MPa or more was obtained at a pressing pressure of 2.5-7.5 MPa for the opoka of Avilo-Fedorovskoye deposit with a raw material moisture content of 25-35%, and for the Shevchenkovskoye deposit opoka mainly at a molding moisture content of the ceramic mass from 10-25%.

The patterns of dependence of the density of molded samples on the molding moisture content and pressing pressure obtained using the rigid extrusion method for opoka-like rocks are shown in Fig. 8 and 9.

Experimental work revealed that the relationship between the density of raw material products and pressing pressure and molding moisture content is not strictly linear. As these values increase, a significant increase in the density of molded samples from both Avilo-Fedorovsky and Shevchenkovsky deposits is observed, followed by a gradual stabilization of density values. The increase in density of raw material from opoka of Avilo-Fedorovsky deposit continues with an increase in the moisture content of the ceramic masses from 25% to 35%, and from 10% to 25% for Shevchenkovsky deposit. The initial amount of water, determined individually for each opoka, acts as a lubricant in the molding masses, and the opoka particles, crushed under varying pressing pressures (in this case, from 2.5 to 7.5 MPa), freely occupy space in the molding masses and are compacted by convergence under the applied load. Clay particles in the opokas also affect the density of adobe products, as they have a plasticizing effect. The maximum density of samples made from ceramic masses from Avilo-Fedorovskoye deposit—1.74 g/cm3—was achieved under a pressing pressure of 7.5 MPa and a molding moisture content of 35%. For samples from Shevchenkovskoye deposit, the maximum density was 1.8 g/cm3, achieved under the same pressure and a ceramic mass moisture content of 20%. Density growth slows down when overwetting occurs and maximum particle packing is achieved at a given pressing pressure. An important objective in such research is to find the most cost-effective technological solutions: achieving increased molded product density with minimal energy consumption, which will ensure high strength characteristics and the possibility of setting raw ceramic stones directly onto kiln cars.

Based on the results of studies to determine optimal values for pressing pressure and molding moisture content, it was established that it is possible to achieve strength values exceeding 2 MPa and a density of 1.8 g/cm³ in freshly molded ceramic samples based on the studied opokas from Avilo-Fedorovskoye and Shevchenkovskoye deposits. These raw materials characteristics ensure a high degree of preservation of the geometry of tongue-and-groove joints (if present), thin partitions in hollow stones, and an overall flawless appearance when moving pieces between production stages. The main advantage of the increased strength of freshly compacted ceramic stones is the ability to directly load them onto kiln cars with minimal or no drying, which can reduce the production process to 48 hours. Due to the developed natural microporosity of opoka-like raw materials, residual moisture is evenly distributed during heating, preventing critical deformations and cracks. Upon achieving the specified parameters of the molded products, a high economic effect is ensured by reducing the duration of the technological process, minimizing the amount of defective products due to the absence of the need for intermediate transfer of raw materials from drying cars to kiln cars, and reducing energy costs due to the absence of the need for drying.

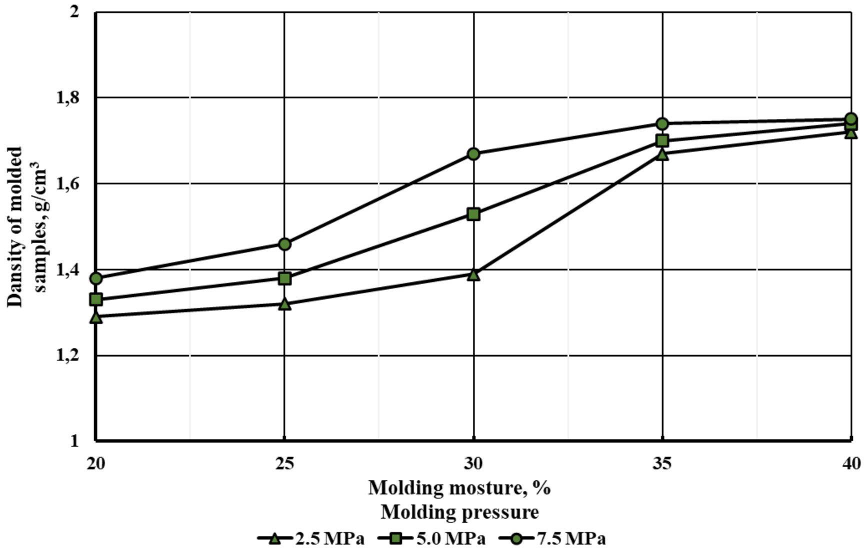


Fig. 8. Dependence of the average density on the pressing pressure at different molding moisture content of freshly molded samples of ceramic mass based on the opoka from Avilo-Fedorovsky deposit.

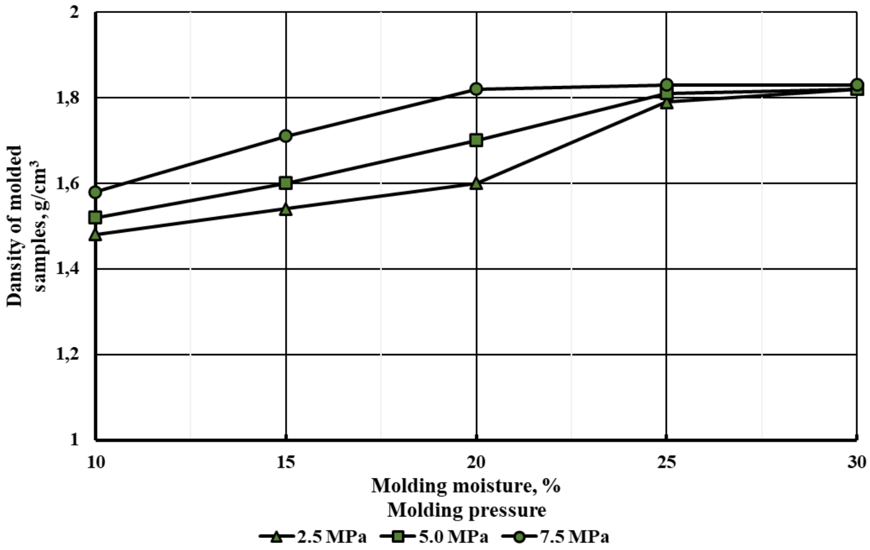


Fig. 9. Dependence of the average density on the pressing pressure at different molding moisture content of freshly molded samples of ceramic mass based on Shevchenkovskoe deposit opoka.

Due to the natural properties of the mineral and chemical raw materials of opoka-like rocks, the firing process of opokas involves a two-stage transformation determined by the properties of opal silica. The first stage is the low-temperature interaction of opal with clay minerals and micas (constant components of the rock), leading to the formation of a liquid phase and aluminosilicates. The second stage is the polymorphic transformation of the opal itself into cristobalite, which intensifies upon heating to 1100°C. If firing is performed in the range of 1050–1100°C (without transition to full clinkering), the final structure of the material is predominantly cristobalite, the peaks of which increase with increasing firing temperature, as can be seen in the X-ray diffraction studies shown in Fig. 10 and 11. Accordingly, such ceramics can be referred to as cristobalite or, given the presence of a glass phase, glass-cristobalite.

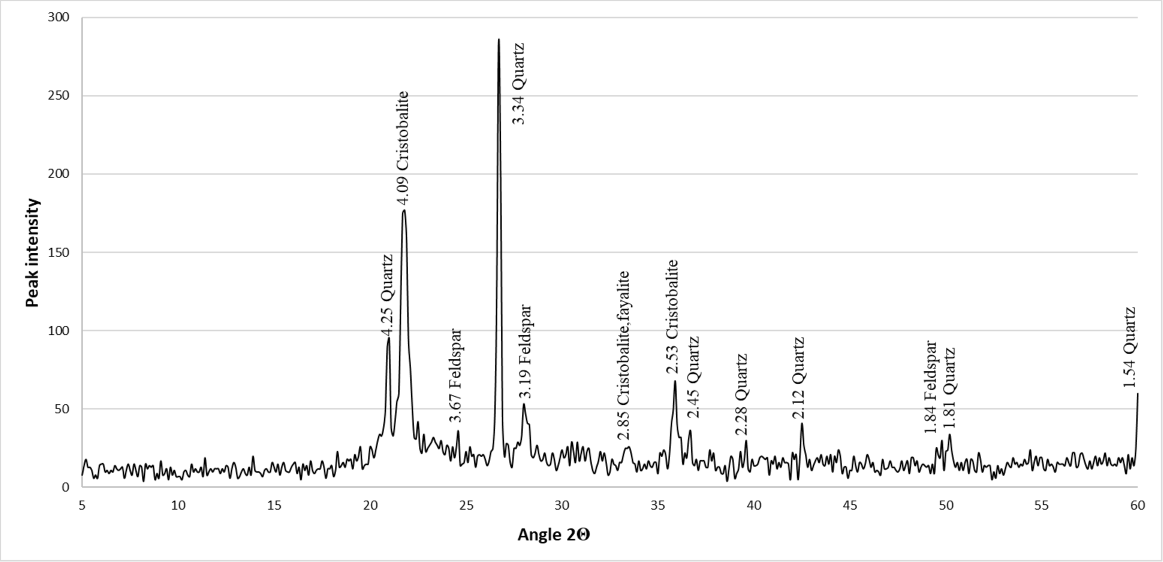


Fig. 10. X-ray image of the fired ceramic sampls based on the opoka of Avilo-Fedorovskoye deposit with temperature 1050 °C.

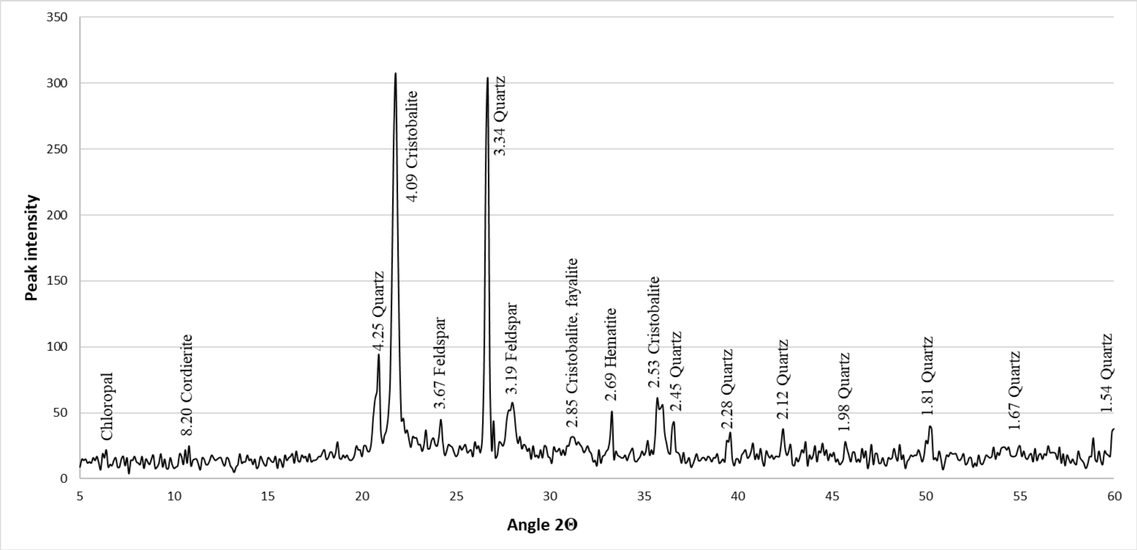


Fig. 11. X-ray image of the fired ceramic sampls based on the opoka of Avilo-Fedorovskoye deposit with temperature 1100 °C.

A characteristic feature of opokas is their high natural microporosity, with an effective pore diameter ranging from 0.5 to 1.3 pm. This microporosity is independent of the degree of mechanical grinding of the raw material during preparation and is fully preserved in the material after firing at various temperatures, in our case both at 1050°C and at 1100°C (Fig. 12). Due to this, ceramic bodies made from opokas are characterized by a lower density (1300–1600 kg/m³) while exhibiting relatively high compression strength, which ranges from 20 to 40 MPa depending on the initial rock composition and the heat treatment temperature. This combination of properties opens the possibility of producing large-sized ceramic stones with high void content (up to 50–60%). Combined with the low density of the body itself, this allows us to produce products with an average density of 500–700 kg/m³ and strength characteristics of 10 MPa and higher.

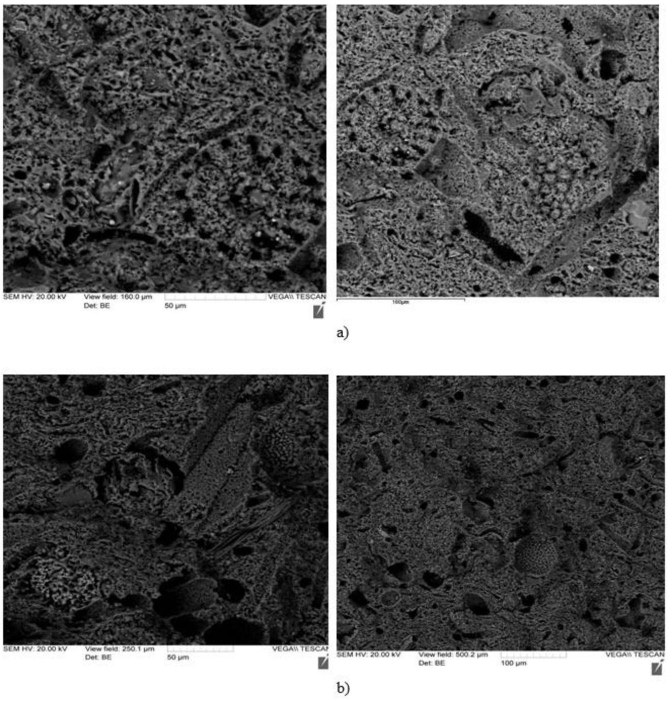


Fig. 12. Electron microscopic photographs of sampls based on the opoka of Avilo-Fedorovskoye deposit with temperature a) 1050 °C; b); after 1100 °C.f.

4. CONCLUSIONS

The production of an efficient porous ceramic body is a key strategic objective, defined by raw material, economic, and environmental reasons. For Russia, which possesses vast reserves of siliceous rocks, the most rational approach is to explore various technologies for exploiting this raw material. This approach not only addresses the challenge of creating competitive, heat-efficient materials but also contributes to resource conservation, import substitution, and environmental issues. Further research should focus on formulating compounds, developing standards for new raw materials, and creating production lines adapted to regional resource bases. Rigid extrusion is a technologically and economically feasible method for forming ceramic products based on opoka-like rocks. Optimizing the charge material composition and extrusion parameters will produce materials with high performance characteristics. This production method is particularly effective for producing large-format porous blocks with horizontal voids, which combine high load-bearing capacity and thermal insulation properties. It is necessary to experimentally determine the optimal moisture content, pressing pressure, and other characteristics for each specific opoka-like rock to produce high-quality wall materials. This article presents a part of a research work that, using rocks from Avilo-Fedorovskoye deposit, classified as "normal" opoka varieties, and clay opoka from Shevchenkovskoye deposit as examples, defines an algorithm for working with opoka-like siliceous raw materials as the main component to produce freshly molded products with optimal process parameters. A distinctive feature of siliceous raw materials, as noted in the article, is their low plasticity and high porosity, which leads to increased molding moisture content in ceramic masses and, consequently, a high risk of cracking and deformation during drying and firing. The rigid extrusion method was determined to be the most cost-effective and suitable for producing large-format ceramic wall products from such rocks, as it ensures increased compaction of the charge particles and the formation of a homogeneous porous structure of the ceramic body. Due to their developed natural microporosity, fired products based on opoka-like rocks will have the required strength characteristics and thermal properties, have average density values of up to 700 kg/m³ and a compression strength of more than 10 MPa, which is sufficient for the production of high-void large-format ceramic stones based on the specified raw materials.

REFERENCES

1. Munir M., Kazmi S.M.S., Gencel O., Ahmad M., Chen B. Synergistic effect of rice husk, glass and marble sludges on the engineering characteristics of eco-friendly bricks. Journal of Building Engineering. 2021. 42. P. 102484.
2. Munir M., Abbas S., Nehdi M., Kazmi S.M.S. Development of Eco-Friendly Fired Clay Bricks Incorporating Recycled Marble Powder. Journal of Materials in Civil Engineering. 2018. 30 (5). P. 1 – 11. 19435533.
3. Gencel O., Munir M., Kazmi S.M.S., Sütçü M., Erdoğmuş E., Velasco P., Eliche-Quesada D. Recycling industrial slags in production of fired clay bricks for sustainable manufacturing. Ceramics International. 2021. 47 (2). P. 2456.
4. Saleem M., Kazmi, S.M.S., Abbas S. Clay bricks prepared with sugarcane bagasse and rice husk ash – A sustainable solution. MATEC Web of Conferences. 2017. 120 (7). P 456.
5. Sütçü M., Akkurt S. The use of recycled paper processing residues in making porous brick with reduced thermal conductivity. Ceramics International. 2009. 35 (7). P. 2625 – 2631.
6. Sütçü M., Gencel O., Erdoğmuş E., Koc V., Çay V.V, Gok M. Properties of bricks with waste ferrochromium slag and zeolite. Journal of Cleaner Production. 2013. (59). P. 111 – 119.
7. Buravchuk N., Guryanova O., Parinov I. Use of technogenic raw materials in ceramic technology. Open Ceramics 2024. 18. P.100578.
8. Rakhimova G., Stolboushkin A., Vyshar O., Stanevich V., Murat Rakhimov M., Kozlov P. Strong structure formation of ceramic composites based on coal mining overburden rocks. Journal of Composites Science. 2023. 7 (1). P 209 – 221.
9. Avizovas R., Baskutis S., Navickas V., Tamándl L. Effect of Chemical Composition of Clay on Physical-Mechanical Properties of Clay Paving Blocks. Buildings. 2022. 12 (7). P. 943.

10. Kalendova A., Kupková J., Urbaskova M., Merinska D. Applications of Clays in Nanocomposites and Ceramics. Minerals. 2024. 14 (1). P. 93 – 103
11. Gualtieri S. Ceramic raw materials: how to establish the technological suitability of a raw mate-rial. Archaeological and Anthropological Sciences. 2020. 12. P. 183.
12. Kotlyar V., Terekhova Yu., Lapunova K., Maltseva I. Characteristics and raw material base of siliceous-carbonate rocks as raw materials for the production of synthetic wollastonite. Bulletin of Tomsk Polytechnic University. Georesources Engineering. 2025. 336 (6). P. 84 – 95.
13. Kurilova S., Naumov A., Gebru B. Silica clay (opoka) as a promising raw material for unfired wall products by compression molding. E3S Web of Conferences. 2023. P. 419.
14. Kotlyar V., Terekhova Yu.. Mineralogical, chemical and structural features of opoka-like opal-cristobalite rocks as raw materials for the construction industry. Bulletin of Tomsk Polytechnic University. Georesources Engineering. 2023. 334 (1). P. 145 – 155.
15. Zemlyanskaya A., Lapunova K., Semenova M. Dry masonry mixtures based on siliceous opal-cristobalite rocks for clinker bricks. Construction materials and products. 2024. 7 (2).
16. Endell J. «Röntgenographischer Nachweis kristalliner Zwischenzustände bei der Bildung von Cristobalit aus Kieselgur beim Erhitzen». Kolloid-Zeitschrift. 1948. 111(1). P. 19 – 22.
17. Kandymov N., Korpayev S., Durdyev S., Myratberdiyev R., Gurbanmyradova L. Manufacturing of Fired Clay Bricks for Internal Walls with Dolomite Residue as a Secondary Material. Buildings. 2023. 13 (12). P. 3065.
18. Goncharenko D. Experimental testing of clincer brick for suitability using for sewer collectiors reconstruction. Collection of scientific works of the Ukrainian State University of Railway Transport. 2019. 187.
19. Erdoğmuş E., Sütçü M., Hossain S., Bayram M., Sari A., Gencel O., Ozbakkaloglu, T. Effect of molding pressure and firing temperature on the properties of ceramics from natural zeolite. Construction and Building Materials. 2023. 402. P. 132960.
20. Jorgensen T., Lightfoot S. Twisting Clay: Creative Research to Explore the Complex Rheology in Ceramic Extrusion. FormAkademisk. 2023. 16(4). P. 1 – 11.

INFORMATION ABOUT THE AUTHOR

Zemlyanskaya A.G., e-mail: ya@azemljanskaja.ru, ORCID ID: https://orcid.org/0009-0009-6316-3193, Don State Technical University, Candidate of Engineering Sciences (Ph.D.), Associate Professor of Construction Materials Department